Introducing Advanced Driver Assistance Systems: Some Legal Issues

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The introduction of Advanced Driver Assistance Systems (ADAS) in road traffic induces many complex questions. One of them is whether or not present legislation frameworks are able to accommodate a smooth development and market implementation of ADAS. This is strongly related to the aspect of traffic safety. The various aspects related to this issue are categorised based on an exploration of the functionality and possible failure of ADAS. Next, some problem categories are more in-depth elaborated. In particular attention is paid to the need for establishing safety requirements to the design and marketing of ADAS as well as the issue of liability regulation. It is concluded that decision making on safety requirements mainly takes place at an international level. However, so far hardly any requirements regarding ADAS have been laid down in compulsory rules yet. It is further concluded that current legal frameworks in both the fields of vehicle safety standards and liability provide for (some) flexibility towards technical developments regarding ADAS, i.e. these frameworks do not contain many 'hard rules' obstructing the introduction of ADAS. Concerning the safety regulation of ADAS it is argued that the speed of technological developments and the innovative and specific nature of ADAS technology generate various tensions. These tensions should have consequences for the weight that is put on public and private intervention mechanisms and the relation between preventive safety standards and reactive regimes such as product liability and post-market controls.

1. Introduction

There is much interest from automotive industries, drivers, fleet owners and public transport authorities to introduce advanced driver assistance systems (ADAS) in road traffic. These systems refer to electronic devices for the support of drivers in performing various driving tasks (such as merging, speed control or lane keeping). With respect to these driver tasks, examples of such systems are speed-headway keeping, front or side collision avoidance systems, lane keeping systems, systems for vehicle control or safety readiness. The technology is generally based on the concept of collecting data on the vehicle behaviour and its direct environment (sensor function), analysing patterns in these data while matching these patterns with decision rules (intelligence) and activation of certain driver support functions (Hall, 1995). These support functions might bear the nature of informing the driver by giving some signal (e.g. on speed limit exceeding), assisting the driver (e.g. by giving some contra-power on the steering wheel) or overtaking control (e.g. advanced cruise control). The more mature systems that have been developed and implemented at the market are based on purely in-car technology (e.g. advanced cruise control). However, more complex support systems (such as intelligent speed adaptation) require some system components outside the vehicle, for instance for precise vehicle positioning. Therefore it is expected that future advanced driver assistance systems will be increasingly based on a combination of in-car and infrastructure based technology. This will significantly increase the complexity of the development and implementation of these systems. However, expectations about the advantages of these systems for traffic performance are high (improved road capacity use, more safety, less emissions) (see e.g. Broughton, 1994; Kanaris et. al, 1997). Therefore, this complexity does not seem to be a reason for automotive industries nor public authorities to slow down on the avenue of research, development and market implementation, in particular since these efforts are embedded in the broader application of Intelligent Transport Systems technology (Van der Heijden & Marchau, 2001). The complexity of advanced driver assistance systems evidently involves the technical dimension. First, when these systems are to be used in complex traffic situations (such as in urban traffic or on secondary roads), high performance requirements are put to the situation recognition by the implemented intelligence. This implies an increase of data to be collected and speed of pattern recognition. In particular when the support function is based on the interactive use of in-car intelligence and communication with some infrastructure facilities outside the car (e.g. magnetic needles in the road, roadside sensors or satellite communication) this becomes a highly complex technological challenge. A failure-proof approach to carrying out this task is yet to be found (Naab & Hoppstock, 1995). As Ward (1997, p. 75) argues: “the most difficult technical challenge facing this new systems is less the sensors themselves than this job of interpreting what the sensor sees”. Another aspect of technical complexity is the reliability of the computer software in relation to the issues of electromagnetic interference and mutual unforeseen interaction between different electronic systems. There is empirical evidence that due to such mechanisms systems might be activated (e.g. brakes) such that driving performance is negatively influenced. Finally, including more and more complex ADAS requires transparent man-machine interfaces. It should be completely clear for the driver when and how to use various systems. Again, recent research indicates that misuse is easily to be generated (e.g. Hoedemaeker, 1999).

Partly due to the growing awareness in recent years about the technical complexity increasingly attention has been asked for the non-technical complexity of the development and implementation of ADAS (e.g. Levine and Underwood, 1996; Marchau & Van der Heijden, 1998; Marchau, 2000). Here also it is referred to a variety of issues. A first issue concerns the uncertainty on the impacts of the large-scale application of ADAS on the traffic performance. So far, many of the positive expectation are not based on empirical evidence, but on small-scale experiments. For instance the study by Minderhoud (1999) on advanced cruise control indicates that a significant increase of road capacity is only to be reached under very strict conditions on market penetration and use. Further, doubts on the safety impacts of various systems have been articulated (Marchau et. al, 1999). Moreover, related to the technical complexity discussed before, the applicability of ADAS seems to be limited to.

The second issue concerns the question how limited applicability and uncertainty on impacts match with public policy goals and influence market adoption. Do potential users consider the price – quality relationship satisfactory for purchasing these systems? What will be the preference of drivers with respect to the acceptable degree of automation? Will driver support systems take the form of autonomous operating technology, eliminating the responsibility of the driver? Or is it imaginable that some of the driver support systems are based on warning devices and others not?

Finally, the issue of liability is of increasing relevance. In the case of assisting and autonomous operating ADAS, the liability position of drivers linked to accidents is questioned (Syverud, 1993; Janker, 1995; Van Wees, 1999a,b). Another important issue raised, which may also be linked to the issue of liability, is that of specifying quality standards, certification procedures and the position of regulatory authorities and production industries.

This article aims at elaborating on this issue of legal regulation. It is based on recent research performed as part of a larger research program on the technology assessment of automated vehicle guidance technology (Van der Heijden & Wiethoff, 1999). The research project aims at answering the question to what degree the existing European legal framework is able to smoothly accommodate developments in the field of ADAS. The reason to pay serious attention to this issue is because some authors have argued that perhaps current liability regulation might be a ‘show stopper’, while others have stressed its potential decelerating impact on market implementation (e.g. Randal Ayers, 1994; Burris, 1996; Feldges, 1997).

The structure of this article is as follows. First, the issues on this subject will be structured in section 2. Next, in section 3 the issue of safety requirements to automotive products’ development will be addressed. Section 4 than goes into detail with respect to the issue of liability. Next, section 5 presents some discussion on how to deal with the information presented in the previous sections: what are basic dilemmas? The article ends with conclusions in section 6.

2. Structuring the issues

In the introduction a number of developments have been briefly described. It has been indicated that various uncertainties exist with regard to these developments. Some of these uncertainties generate legal questions that might lead to slowing down the speed of ADAS implementation.

Dominant in the discussions on these legal questions is the issue of liability in case of accidents. In the current situation without large-scale use of ADAS, accidents are mainly evaluated in terms of responsibility of the involved road users. In that view accidents generally are the result of either non-intended or purposeful deviation from generally accepted rules. Once these human errors have been reconstructed in the context of accidents, they might serve as a reason for qualifying certain road users as responsible for the occurrence of the accident (’name and blame’). Hence, in current practice also liability questions regarding traffic accidents mainly focus on the driver or the owner of the vehicle that 'caused' the damage. With the introduction of ADAS, this situation may change. If an accident can (also) be traced back to an (alleged) 'malfunctioning' of the vehicle, than not only the question is raised to what extent the car driver/owner of the vehicle can be held (legally) responsible, but also which other persons such as manufacturers and road authorities may be liable for the damage. These questions are most prominent in case of assisting and autonomous operating ADAS. In case of informing devices the driver simply receives more or other information to take his/her decision. An example is the already frequently used in-car route guidance system helping the driver to find his/her route more easily. It should be stressed however, that these systems may create certain dangers too. Wrong information to the driver might cause uncertain driver behaviour, hence might create a non-adequate situation awareness and consequently generate driver errors.

The question of changing of responsibilities more directly occurs in case of assisting and autonomous operating ADAS. An example is the limitation of maximum speed by the use of an Intelligent Speed Adapter (ISA) that automatically reduces the speed up to the local limit. The situation might easily occur that the ISA is not informed of the fact that in certain situations the maximum speed limit is temporarily reduced because of special circumstances (e.g. road works). A driver who heavily relies on the ISA might therefore more or less unconsciously exceed speed limit. Once involved in an accident, the role of the ISA in relation to the driver’s behaviour might be questioned. Another example is the fact that the advanced cruise control of certain busses in Eindhoven, the Netherlands, got activated due to electromagnetic interference causing at least one serious accident with casualties.

Finally, assisting and autonomous operating ADAS also add new dimensions to the relationship between drivers and road management authorities. Of course, in the present situation the road manager plays a significant role already. This authority is responsible for providing adequate road infrastructure complying with generally accepted standards for road design, as well as means to accommodate traffic in a safe way (such as traffic light installations). In respect to certain ADAS the road manager is likely to get additional responsibilities; in the above-described speed control situation for instance the need for providing up-to-date information on temporal speed limits. This might imply the need for adding certain facilities to the infrastructure (such as magnetic nails or infrared communication sensors) and the obligation to maintain on these facilities. But even when drivers and road managers perform well, the performance of certain ADAS becomes questioned. Do these systems always do what they are supposed to do in certain circumstances (functional reliability)? Are these systems functional robust and can they cope with unknown situations? Are the users well instructed when and how they should use the system? How does one prevent drivers to over-estimate the functionality of the system in use? Fledges (1997) refers to an experience with anti-block systems (ABS). A number of users were mistaken in their expectations that the system would shorten the braking distance,

which resulted in shorter speed-headway following causing more accidents than with cars not being equipped with such a system. Hoedemaeker (1999) describes how car drivers in an experiment have wrong expectations on the assisting function of advanced cruise control, causing dangerous traffic situations. In case of certain accidents where ADAS is involved, the focus might switch from the driver's responsibility for human errors to the functional quality of the applied system and hence the product liability of the producing industries.
Questioning the responsibility of the producing industries brings us to switch the focus on the quality of the process of ADAS development, production and marketing. This implies attention for issues of specification (and standardisation) of functional requirements, quality testing, certification and providing for adequate selling conditions. Evidently, the aim is prevention of introducing not well performing ADAS on the market. Producing industries have a primary responsibility for that. However, regulatory authorities have a serious responsibility too. Which quality standards can be applied? Are these standards the same for every market (e.g. different states)? Can uncertainty due to limited empirical knowledge on the impacts of ADAS on the traffic system satisfactorily be transferred into product specification requirements or should the focus lie on process requirements for production, certification and marketing? In automotive industries, various regulatory regimes exist involving state-based as well as international rules. Consequently, we deal with a complex regulatory environment facing a new technology with relatively unknown impacts.
Summarising, a variety of legal aspects of ADAS emerge. Important questions focus on the issue of creating safety and arranging legal responsibility. It is clear that all parties involved such as drivers, vehicle owners, production industries and road authorities, have a basic responsibility for safe traffic and the use of ADAS therein. However, the innovative nature of the technology yielding new dimensions in the relationship between drivers, vehicles and the driving environment generates specific questions related to legal responsibilities for safety and liability for accidents. Uncertainties about legal responsibilities and consequences for regulatory regimes may hamper product development and market introduction of these systems. In the rest of this article some of these legal issues will be further explored. The focus will be on safety standards and liability of motorists and manufacturers.

3. (Establishing) safety requirements and ADAS development

The development of motorised vehicles has always been determined by pre-specified safety requirements. Evidently, this is because of the need to prevent for introducing vehicles that do not meet a minimum safety level. Safety requirements focus on conditions for the construction and performance level of vehicles and included equipment. This vehicle regulation framework is increasingly the result of international deliberation and decision making. The main objective of international harmonisation of vehicle safety standards is the creation of open markets. Consequently, the national influence is strongly limited.
A first to be mentioned international platform is the Working Party on the Construction of Vehicles (WP29) of the United Nations Economic Committee for Europe (UN/ECE). This Working Party was installed in 1952. In 1958 an agreement was established to facilitate the adoption of uniform conditions of approval and the reciprocal recognition of approval for motor vehicle equipment and parts. Based on this so-called 1958 Agreement, a variety of specific rules has been elaborated and accepted. Individual states can accept these rules

voluntarily; they do so by not officially objecting to the proposed specific rule. Until 1995, given the European focus of the Working Party, the states involved are European states. These activities within the UN/ECE therefore consequently bore a European character. Non-European countries such as the USA and Japan had the status of observer. In practice however, these countries actively participated in the preparatory deliberations of the rules. This situation has changed in 1995 with the revision of the 1958 treaty. Since 1995 non-European countries is offered the opportunity to become full member of the UN/ECE. For example Japan and Australia have done so in the meantime. However, Canada and the USA did not because of their own national systems of regulation of vehicle safety requirements. From an economic point of view, this is not a very desirable situation, since during the nineties of the past century there is a strong tendency to open global markets. And the more automotive markets are opened, the stronger the need for global harmonisation of safety standards. Different regulatory regimes in different global areas do not match to this idea. Therefore, Europe, the USA and Japan have invested in co-operation after 1995 to come to a worldwide agreement on vehicle requirements. This resulted in a new treaty (the 1998 Global Agreement) in addition to the 1958 Agreement and the change of WP29 into the so-called World Forum on the Harmonisation of Vehicle Regulation.

The second important international platform for European countries with regard to establishing vehicle requirements is the European Union. The work of the EU in the field of automotive safety requirements has been strongly influenced by the aim of the EU erection in 1958: the creation of an open market within Europe. Regulation at EU level is therefore strongly focused on eliminating market barriers at state level and stimulating free trade and persons and capital flow within Europe. National differences in vehicle safety standards easily works as a barrier for free trade in motorised vehicles, which is strengthened by the fact that various European countries have strong economic interests in automotive industries. Because of the economic value of the automobile industry harmonisation of vehicle requirements within the EU was one of the early priorities (Swaak, 1999). This was done through the drafting of European Directives. Member states have the obligation to implement these directives in their national laws. Difference is made between framework directives and specific directives.

For ADAS development, in particular framework Directive 70/156/EEC is important, because it lays down the procedure for type approval and conformity assessment (certification) of motorised vehicles. This in 1970 accepted directive indicates that a whole vehicle or vehicle components, certified in one of the European states (based on compliance to European safety requirements), cannot be excluded from markets of other states unless there is sufficient evidence that it would be seriously threatening traffic safety. Based on this framework directive a large number of specific directives have been drafted laying down requirements for different aspects and components of motor vehicles. For one category of motor vehicles (luxury cars) the harmonisation process has been completed. It means that for all relevant aspects and components of this type of vehicle, directives have been drafted and a European type approval for the whole vehicle can be granted. Consequently, if a vehicle or components have been type approved in one member-state it will be very hard for another member-state to reject the admittance of such a product for their domestic market.

In this context it should be mentioned that the general directive on vehicle regulation has included a procedure for a more flexible response to fast technological developments, given the fact that formal regulation takes a long period. The procedure introduces a special

committee with representatives of EU member states, advising on the acceptance of certain new technological developments not in conformity with existing standards. In case new technologies are accepted, this should also lead to changes in the specific directives. Evidently, for such technologies as ADAS this committee might play an important role. On the other hand, the procedure is criticised for its lack of democratic control, more or less excluding the European Parliament from the decision making process. Furthermore this approach may lead to 'ad hoc' regulation. For these reasons setting up new directives may be preferred.

With regard to the process of setting vehicle safety standards it is also important to notice that the actual rulemaking is likely to shift more and more in the direction of the above mentioned UN/ECE committee. This is due to the fact that the EU as a supra-national political and administrative organisation has become member of the UN/ECE in 1997. Although experts from the different member states may still take part in the deliberations within UN/ECE, the EU remains to keep the formal voting power on draft regulations.

The preceding brief overview indicates that the specification of vehicle safety requirements is heavily dominated by the work of international authorities. For European states the EU and the UN/ECE are important. The importance of specific state law is reducing rapidly. Opening international automotive markets implies harmonisation of requirements at an international level. Consequently, ADAS development and implementation is also regulated at these decision levels. The fact is however that so far no specific directives for ADAS have been developed within Europe or can be accepted from the work by the UN/ECE committee. In other words: no clear and formally binding ADAS safety requirements have been specified yet. Nevertheless, debates have started. In UN/ECE discussions have been started and some drafts have been made with respect to complex electronic systems, Advanced Cruise Control and Intelligent Speed Adapters. At EU level the European Commission recently (2000) published a recommendation with regard to the safe and efficient in-car application of information and communication technology in motor vehicles. This (non-binding) document contains a "Statement of Principles on human machine interface for in-vehicle information and communication systems" but bears an explorative character. It calls upon the automotive industry to work on a mutual agreement on applying certain principles of human-machine interface. In fact, it can be interpreted as an attempt to establish 'soft' law.

This cautious EU approach is to be explained by the fact that we face a new technology and unknown effects of applications of this technology. There exists considerable uncertainty and limited knowledge that appears to be a too fragmented and soft basis to specify ADAS safety requirements. Moreover, the speed of changes in the technological possibilities is high. The absence of specific ADAS safety standards invites ADAS manufacturers to seek for certification of their product in a European state that is most suitable for them. In addition, European directives to a high degree assure the further access to other state markets. This mechanism has been qualified as forum shopping. The lack of clear directives and the possible threat of forum shopping might at least partly be solved by applying what is called the new approach. This approach has been implemented in general EU regulation mid '80 and focuses on product regulation dominantly based on the operational work of normalisation institutes. However, vehicle requirements have so far not been made subject of this new approach. It is therefore clear that we still have a long way to go before a convincing set of safety requirements for ADAS has been internationally agreed upon.

4. Liability issues regarding ADAS

In general, automotive industries, public authorities and drivers all have a high sense of responsibility for realising safety in traffic. This implies the design and construction of safe vehicles including the in-car equipment. It further implies the construction and maintenance of functionally transparent road networks and effective traffic flow management systems. And it implies cautious driving behaviour (on average). Notwithstanding these efforts, accidents might happen. In future an increasing number of accidents will be (partly) based on the use of ADAS. In those situations, there is the question of responsibility and the question of liability. This section deals with this latter issue. The issue of liability refers to an extended field of sub-issues. Since this is a complex issue, as was the case in the previous section with safety requirements, only some mainlines can be described (see for more details e.g. Van Wees, 1999b).

4.1 Liability of involved road users

Thinking about liability for ADAS-related accidents it is important to realise that in general, protection of traffic accident victims is an important goal of traffic accident liability law (Tunc, 1998). This rationale not only induced most European legislators to provide for special liability rules but is also expressed in systems of mandatory vehicle insurance. Victims can claim their damages directly from the insurance company and the insurance companies involved mutually settle their positions in a certain case. The mandatory insurance system protects both the liable owner/keeper of the motorised vehicles and the victims of the traffic accident. It guarantees that, in case of liability, sufficient financial resources are available to compensate damage.

When looking at existing traffic accident liability rules in different European countries, roughly three types of accident compensation regimes are identified: fault liability, strict liability and road traffic insurance. We will respectively discuss these regimes.

Fault liability refers to general rules for personal liability, based on generally accepted notions of behaviour of citizens: “be a careful citizen, mindful of your duties towards yourself and your fellow citizens”. Negligent behaviour or purposeful violation of this rule is a requirement for liability, implying that there will be no liability if a careful driver could not have prevented the accident. In the context of failing ADAS or improper use of ADAS, directly or indirectly causing an accident, negligent behaviour might become more difficult to prove. The driver basically has more possibilities of an absence-of-fault defence. This is rather obvious in case some ADAS system fully takes over a certain drivers’ task leaving no room for corrective action from the driver. Of course more discussion on the validity of such a defence is possible in the context of assisting systems leaving the driver some freedom of operation. Whether an absence-of-fault defence will be successful then depends on the special circumstances and facts of the case, in particular the question whether the driver could have ‘reasonably’ avoided the accident. It is the judge who has to decide on that. In The Netherlands, the tendency is that judges take the ‘perfect’ driver and not the ‘reasonable’ driver as the benchmark for deciding whether a driver is legally responsible for the accident.

The dangers involved with motorised traffic have induced most European legislators to provide for special, more victim-friendly, liability rules additional to the general fault liability rules. Most of these additions explicitly put liability directly on the owner or keeper

of the vehicle, even when there is no evidence for faults. Therefore, this category of rules is called the *strict liability* regime. For instance in The Netherlands, the owner or keeper of the vehicle is liable for the damage caused by the vehicle unless it is assumable that the accident can be attributed to 'force majeure'. This means that there will be no liability in case the accident is caused by external factors. Most European countries have strict (or no-fault) liability rules although significant differences can be identified in terms of the protection of categories of victims and damage (De Haas & Hartlief, 1998). In the Netherlands, in case of an accident with motorised road users involved, only non-motorised road users (cyclists and pedestrians) can put liability claims on the owner/keeper referring to strict liability rules. In other countries also passengers (e.g. Belgium) and even drivers (e.g. Spain, Denmark, France) are protected by the strict liability regime. Differences also exist with respect to the degree to which a 'force majeure' defence is possible. For instance The Netherlands and Germany allow for such a defence by owners/keepers. However, the use of in-car driver support systems and their possible failure is not to be considered as a 'force majeure'. In the case of the use of ADAS based on the communication between in-car and infrastructure system components (e.g. Intelligent Speed Adapter) owners/keepers might successfully defend themselves by referring to failing external components of the supporting system.

The third important accident compensation regime is that of *traffic insurance*. Sweden is the only European country in which such a system exists. Under a regime of traffic insurance, the system of 'first party' insurance is introduced which means that victims in each vehicle involved do obtain compensation directly from the vehicle's insurer. In addition non-motorised road users keep protected by the system of third party liability. This regime implies that damage caused by ADAS-related accidents, will be automatically compensated by the insurer of the involved vehicle.

Summarising, in Europe different regulatory regimes exist concerning liability of drivers and car owners. Whether and under which circumstances these persons can be held liable for ADAS related accidents depends on the details of the liability system in question. In short terms, under fault liability regimes drivers and vehicle owners will not be liable if they acted as a careful person. This means that if –as will be the case with ADAS – negligent behaviour in terms of inadequate driver reaction or improper maintenance could become obscured, liability of the driver or owner will be harder to establish due to the possibility of an absence-of-fault-defence. Consequently, the use of ADAS will create uncertainty about legal responsibility. This may increase the number and complexity of lawsuits. This is especially true for systems that interact with the infrastructure or other vehicles. It seems that these consequences are hardly acceptable considering the social desire to protect traffic victims. At least 'innocent' third parties need more protection ("motoring should pay its way").

In most European traffic liability regimes owners/keepers of motorised vehicles are to some degree subject of non-fault liability regimes. Under these regimes it will be harder for the car driver/owner to avoid liability although, especially in case data exchange with the infrastructure or other vehicles, some possibilities may still exist. This is in conformity with the rationale of victim protection. However, these liability consequences may diminish public acceptance among motorists. Insurance companies can play an important role in this field. Not only can they promote the (safe) use of ADAS through their premium setting and acceptance policy, they can also establish that accidents that must be attributed to the malfunctioning of ADAS will not have premium consequences for the insured motorist (from 'no claim' to 'no blame').

4.2 Product liability

When in the analysis of the causes of accidents the role of ADAS becomes increasingly questioned, the issue of product liability comes to surface. In Europe the law on liability for defective products historically developed on a national level. In 1985, however, a general European Council Directive on liability for defective products was introduced (85/374/EEG). According to this Directive, the producer shall be liable for damage caused by a defect in his product. This principle relieves the injured party from proving negligent behaviour of the manufacturer (according to the rule underlying the earlier discussed fault liability regime). The Directive has led to a significant harmonisation of liability for products throughout the EU member states, although still national differences in product liability laws exist. First of all, this is due to the fact that the Directive includes a few optional provisions, where the member states can decide whether or not to implement them in their national law. Moreover the Directive is limited in its scope. For instance, it only applies to cases of death and bodily injury as well as compensation for damage done by the product to another thing, which is furthermore intended for private use. This implies that the European Directive is for instance not covering damage to trucks (not intended for private use) nor to the damaged product itself (the car that was damaged due to e.g. a failing cruise control). Such limits and differences in application regimes do give some space to national liability regimes, although derogation from the European Directive is not allowed. Disputes concerning the implementation and application of the Directive are to be decided on by the European Court.
The European Directive considers a product to be defect when it does not provide the safety a person is entitled to expect taking all circumstances into account. These circumstances include (a) the presentation of the product, (b) the use to "which it could reasonably be expected that the product will be put", and (c) the time when the product was put into circulation. Hence, the starting point is the consumer expectation and the focus is on safety instead of inadequacy for intended use.
The first circumstance, *the presentation of the product*, is in particular relevant in the context of innovative technologies and products, such as ADAS. Inadequate presentation of ADAS or instructions on its use can make the system 'defective'. Manufacturers can influence the safety expectations of consumers (and thereby their liability risk) both positively and negatively by the presentation of the product. Manuals, advertisements or other relevant public information sources may influence consumers' expectations. Since users have no experience with newly introduced ADAS, they are not very well able to assess the dangers involved. For instance, experience with Cruise Control and Anti-Block Systems (ABS) indicate that in a number of cases drivers have been mistaken in their expectations about the functionality of these systems (Feldges, 1997). Drivers expected shortening of braking distance by ABS, causing more accidents with cars equipped with ABS than with cars without. It is therefore highly important that potential users understand the operational characteristics of the systems in order to recognise the inherent dangers of using it in traffic. The driver has to be clearly informed about the functional limitations of the system and the potential risk of unintended use. This is in particularly relevant given the increasing functional complexity of ADAS. And even when the potential danger of the system has been made clearly recognisable, this does not exclude the system from being qualified as defective. Warnings can not neutralise the defectiveness if the lack of safety could easily have been avoided through an alternative design that was economically feasible (Dommering

– Van Rongen, 2000). It is the manufacturer's primary duty to market a safe product and he can not arbitrarily assume one specific pattern of use as 'normal'.

This brings us to the second circumstance mentioned by the European Directive*: the reasonably to be expected use*. Reasonable anticipated use includes more than the intended use of the product. This implies that manufacturers should take into account that some users will not always use ADAS with the necessary care. For instance in Germany the benchmark is the behaviour of "the least informed and most endangered user". Careless behaviour is not a reason to exclude the producer automatically from liability, in particular when such behaviour is to a certain degree foreseeable. An example is the use of Automated Cruise Control with low speed. In legal literature it is assumed that manufacturers therefore have a duty to investigate the safety that can be expected from users. Testing ADAS cannot be limited to technical safety alone, but should include human factors as well. This might imply for instance investigating driving behaviour of different driver categories in experimental situations.

The third circumstance mentioned deals with the *time when the product was put to market*. This aspect in particular deals with the question whether a product could be considered defective given that alternative designs were available at the time of marketing and therefore should have been adapted to the state-of-the-art. If that is the case, perhaps the system should have not been brought on the market at all, or should have been redesigned with safer functional characteristics. The risks of a particular design must be balanced against the benefits of an alternative design. Clearly, the price of the product is an important issue here. An upper class Mercedes will have a higher level of crash worthiness than the lowest priced car on the market. But this does not imply that the last one is defective. It will be a balancing of costs and the seriousness of the risks, between the advantages and disadvantages of an alternative design for the product and the user. However, as ADAS becomes more advanced in terms of the degree of automation and therefore proper functions will be more safety critic, less concessions can be made towards other design criteria such as costs and driver comfort. On the other hand, values as freedom of consumer choice and vehicles being available at reasonable costs will not easily lead to the conclusion that a car will be defective because it is *not* equipped with ADAS.

The time of putting the product into circulation also plays a key role in the so-called 'development risk defence'. According to the Directive, the producer shall not be liable if he proves "that the state of scientific and technical knowledge at the time when he put the product into circulation was not such as to enable the existence of the defect to be discovered". Although this defence in national law was not compulsory, most EU member states have adopted it in their implementation of the Directive. This statement on the scientific and technical state-of-the-art opens important avenues for the manufacturer to defend for product liability, and is therefore highly debated. What efforts may be expected from the product developer to foresee and minimise product risks? How can one objectively specify the scientific state-of-the-art in the field of ADAS development in one moment of time, i.e. the time of introduction? A means for manufacturers to cope with this uncertainty is again to put high requirements to the testing of the system under various circumstances (and the registration of these tests).

This brings us to the important question how the judge will (and should) handle the burden of proof. In product liability cases the burden of proof may often be even more important than the interpretation of the legal concept of a defective product (Stolker & Levine, 1997).

The European Directive on product liability basically puts a claim on the injured party to prove the damage, the defect and their causal link. However, other legal principles allow for a shift of the burden of proof to the other party when the court considers such as reasonable and appropriate in light of the circumstances of the case. Evidently, for a driver it will be extremely difficult to prove that the applied ADAS has caused the accident. The technological complexity of ADAS might be too large. The driver then will have great problems with proving that the product was defective and/or with proving the causal link. In such cases courts could enlighten the injured party's burden of proof by assuming a defect on the basis of the circumstances of the case, when it is clear that the driver used the system in the intended way. Courts in several European countries are willing to facilitate the burden of proof regarding defectiveness by referring to the 'typical course of events' (res ipsa loquitur: the case speaks for itself). It means that the proof is based on plausibility. With regard to ADAS this may be complicated, since both system malfunctioning and human errors (including not rightly responding to the malfunctioning) are generally involved. Moreover, it may be difficult to identify the source of the malfunctioning. To facilitate reconstruction after the accident, a data recorder therefore might be a prerequisite. Perhaps the increased use of ADAS should induce an obligation for inclusion of such recorders in motorised vehicles and the regular maintenance of them. However, it should be noticed that the availability of stored data on system performance and driving behaviour raises additional legal issues such as the question whether these data can be used for other purposes such as criminal charges against the driver.

The clue from these circumstances is that in certain ADAS-induced traffic accidents, the parties involved (including insurance companies) might try to shift liability for traffic accidents towards ADAS manufacturers. This liability threat might hamper the development and marketing of ADAS. Systems developers and car manufacturers may be discouraged if potential liability for ADAS-related-accidents is sufficiently high. An important observation in this respect is however, that although product liability is getting a lot of attention in legal literature, case law on the subject in Europe is rather scarce (Commission of the European Communities, 2001). At this point there is a striking difference with the United States. For instance, where in 1992 Ford faced more than 1000 product liability suits in the US, Ford Europe had just 1 product liability suit in that year (Castaing, 1994). The question is to which factors this can be attributed and what the relevance of these factors is for product liability for ADAS in Europe. Surprisingly, there are no substantial differences in liability conditions and it could even be argued that American product liability law is becoming less consumer protective than the European Directive (van Wees, 2000; Howells, & Mildred, 1998).

The striking differences in number of court cases therefore can not be explained from the differences in product liability regimes, but stems from the significant differences in the way these regimes are implemented in their broader legal systems. Some major differences are:

- First, damage awards as compensation for pain and suffering are generally much higher in the USA than in Europe. Moreover, typical in the USA plaintiffs may be awarded substantial amounts in addition to the compensation for damage to punish the defending manufacturer (so-called 'punitive damages'). These high damage awards for suffering and punishment are a strong incentive to initiate litigation against product manufacturers.
- Secondly, in a product lawsuit in the USA each party hires his own technical and scientific experts. This easily leads to misleading, biased, one-sided or incomplete

information influencing the process (Bergkamp & Hunter 1996). In particular in combination with the jury trial system, this is considered to be a potential threat to scientific and legally sound decisions in court. In Europe party experts are much less frequently used; the focus is on the use of neutral and independent experts appointed by the court.

- Thirdly, in contrast with Europe were product liability is handled fully by professional judges, in the USA juries are involved. It is believed that these juries are more open for selective information presented by the party experts and are less inclined to fully and emotionless investigate the requirements for a defective product (Howells, & Mildred, 1998).

Due to these differences is the legal situation in the field of product liability law in Europe and the USA, although in terms of the underlying principle the same, in practice not comparable. This does not mean that US law is not relevant. It is possible that in future, US law will increasingly influence product liability claim culture in Europe since European lawyers seem to become increasingly inspired by US law.

5. Tensions regarding ADAS development and deployment

In the previous sections, we briefly explored some regulatory regimes relevant for the implementation of advanced electronic driver support systems. In that context we focused on the quality of the product and its intended use: How are safety requirements established and what are the liability positions of users and manufacturers of these systems? Are current legal frameworks able to accommodate a smooth development and market implementation of ADAS? An important conclusion is that the judicial frameworks in both fields of vehicle safety standards and liability provide for (some) flexibility towards technical developments such as the introduction of ADAS in the sense that these frameworks contain not many ‘hard rules’ obstructing the introduction of ADAS. For instance, although safety standards may contain barriers for certain technical concepts such as ‘steer by wire’, the legal framework also provides for the possibility (when certain conditions are met) to approve new technologies that due to their innovative nature can not obviously apply to the existing standards. Furthermore, with regard to ADAS current standards often leave room for interpretation whether these standards are met. Product liability is characterised by open formulated standards. Central criterion for liability is the lack of safety a person is entitled to expect. This creates flexibility towards technological developments, but also generates uncertainty for manufacturers. It is basically a valuable principle that judges take into account all the specific circumstances of an accident. As argued various types of considerations regarding circumstances can play a role in the case evaluation by the judge. We have described some of the possible considerations and uncertainties in that context. They in particularly point at responsibilities at the side of manufacturing industries: careful design, extensive testing of new systems, optimal communication to users, update of basic knowledge, and so on. As such, product liability may serve as an additional, generally formulated safety standard.

Although, from the point of view of unobstructed innovations product liability may be preferred over pre-market safety standards, manufacturers may be more pleased by setting at

least some standards to guide them and to serve as a defence strategy in product liability cases. More important, governments (will) feel the responsibility to guarantee some minimum safety level of ADAS. With regard to ADAS safety regulation, development and marketing, the above-described situation generates various tensions. We will discuss a few of them in this section.

A first and central tension is that between *innovation and safety*. As argued before, manufacturers have the desire to innovate the products they offer to the market: innovation as a selling point. That is a crucial element in their marketing strategy in a very competitive market. Innovation in the automotive market among others implies implementing advanced electronics, including ADAS. Cars including such systems are assumed to be more attractive and might even become a benchmark for followers. To become the market leader based on innovation is the ideal of many manufacturers. For public authorities and users of the product, however, safety is a basic requirement. Safety should not be a negotiable issue. Setting non-negotiable standards implies however knowing 'what' and 'how'. And that's the problem: we do not precisely know yet what ADAS safety is. Consequently, although formal regulation might lead to more protection, it inevitably will take a lot of time and due to that this legislation might not keep up with the speed of technological developments. Moreover, one could argue that intervention through product specifications leads to a reduction of consumer freedom of choice.

The tension between innovation and safety also generates the question about the balance between *national and international* legislation. As argued, the specification of vehicle safety standards is heavily dominated by the work of international regulatory bodies. Harmonisation of vehicle safety standards on an international level does have important advantages in terms of increased competition that (to an important extent) also drives the development of ADAS. Furthermore, as the automobile industry is becoming more and more global, legislative influence is best exercised through trading blocks rather than by individual states. On the other hand, consensus between countries with major differences in culture and economic interest is difficult to reach. Harmonisation should not lead to important delays in standard setting and to lowering standards to an unacceptable common denominator. In the field of traffic safety, this danger seems real since traffic cultures between European states differ significantly. This is illustrated by the fact that today's fatality rates in traffic strongly differ between different states.

The fact that formal legislation may hamper innovation also touches upon the tension concerning the *imbalance in research means and expertise* between manufacturers and public authorities. For instance, the fact that public authorities do not take part in the development process can easily lead to an imbalance in expertise between these parties. The automotive industry is powerful in terms of new product development and the building of a public knowledge infrastructure on technology development, systems design and impacts is dominated by automotive industry efforts. Consequently, automotive industries play a significant influential role in decision-making procedures. However, competition in product development and marketing causes crucial information not to become publicly available or with significant time lags. Even scientific research at universities might suffer from this problem. Furthermore, with regard to certain aspects of ADAS such as the use of software, it may be difficult or even impossible to define objective product safety specification. This can only partly be compensated by shifting the focus to development process quality criteria. The

inability to objectively assess the safety of ADAS in a pre-market phase should be compensated by stronger public post market controls (warnings, recalls, etc.).
In the slipstream of this knowledge dissemination and pre-market safety assessment issue, a point of concern is that international harmonisation of vehicle standards and mutual recognition agreements may lead to forum shopping. Manufacturers and traders may seek out those national conformity assessors who are willing to interpret existing standards in a way that is most favourable in terms of the unobstructed introduction of ADAS. This danger is especially latent within the European framework of whole vehicle type approval for passenger cars in combination with the lack of specific rules for ADAS. This problem may (partly) be solved by strengthening the co-operation between type approval authorities and by providing the national states with more possibilities to take action when traffic safety may be threatened (including post-market control measures).
The tension between innovation and safety finally generates the question to which degree intervention in ADAS development and deployment should be based on *public or private intervention.* In legal terms this immediately refers to the weight that is put on respectively public law regimes versus private law regimes. Given circumstances as the pace of technological developments, the research and financial efforts involved in the formulation of safety standards and test procedures, more responsibility may be given to manufacturers to mutually agree on process quality criteria based on state-of-the-art scientific and technical insights. This could lead to more flexibility and acceptance within the industry than can be reached in case of formal regulation with regard to these issues. The use of self-regulatory standards should take place within some regulatory framework, for instance in line with the so-called new approach, to insure that at least some mandatory safety requirement will be met.

6. Final remarks

Advanced driver assistance systems are increasingly introduced in road traffic. Various innovative opportunities have been described in literature on this subject. Their implementation is coloured by several serious uncertainties. The most basic uncertainty is related to the fact that important pieces of knowledge about the performance and applicability of ADAS still lack. In the slipstream of this uncertainty, another source of uncertainty concerns doubts on whether legal regimes are adequate to cope with ADAS or that they might create problems with regard to their development and implementation.
One of the main conclusion from this article is that the present judicial frameworks in both the fields of vehicle safety standards and liability provide for (some) flexibility towards technical developments regarding ADAS in the sense that these frameworks do not contain many ‘hard rules’ prohibiting the introduction of these systems. This, of course, does not imply that there is no apparent need for ADAS safety standards, especially from a product safety policy perspective. It was argued, however, that concerning the safety regulation of ADAS the speed of technological developments as well as the innovative and specific nature of ADAS technology generate various tensions. These tensions may (need to) have consequences for the weight that is put on public and private intervention mechanisms and the relation between preventive safety standards and more reactive regimes such as product liability and post-market controls.

These (potential) shifts should, however, not result in a 'sit and wait' attitude of public authorities. In particular it is important to invest more in building a shared and public knowledge base regarding ADAS. European research programs are important in that context, but not sufficient. More investments in public knowledge development at member state level is not a luxury given the possible significant impacts of ADAS on national traffic policy. The challenges we face in this context are of great importance for each of us. Consequently, a careful public evaluation of developments and decision making on policy measures in this field is highly important. We will therefore follow these developments with great interest.

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